Sensitivity Analysis for Joint Inversion of Ground-Penetrating Radar and Thermal-Hydrological Data from a Large-Scale Underground Heater Test

Michael B. Kowalsky, Jens Birkholzer, John E. Peterson, Stefan Finsterle, Sumit Mukhopadhyay, and Yvonne Tsang
Contact: Michael B. Kowalsky, 510/486-7314, mbkowalsky@lbl.gov

RESEARCH OBJECTIVES

To develop site-specific hydrological models, the joint analysis of hydrological and geophysical data has the potential to significantly improve the characterization of the subsurface, and thus increase the reliability of model predictions. The merit of any given data type depends on its usefulness in providing quantitative information about flow and transport properties (at a reasonable resolution). Since geophysical data offer valuable information on the subsurface structure, developing methods for integrating such data with hydrological data has the potential to significantly advance site characterization in complex, heterogeneous systems.

The objective of this research is to develop a joint inversion approach so that it can be applied to increasingly complex thermal-hydrological processes. These processes include the transport of water, water vapor, air and heat in fractured porous media, the transitions between the liquid and gaseous phases, and vapor-pressure lowering effects as a result of capillary pressure increases.

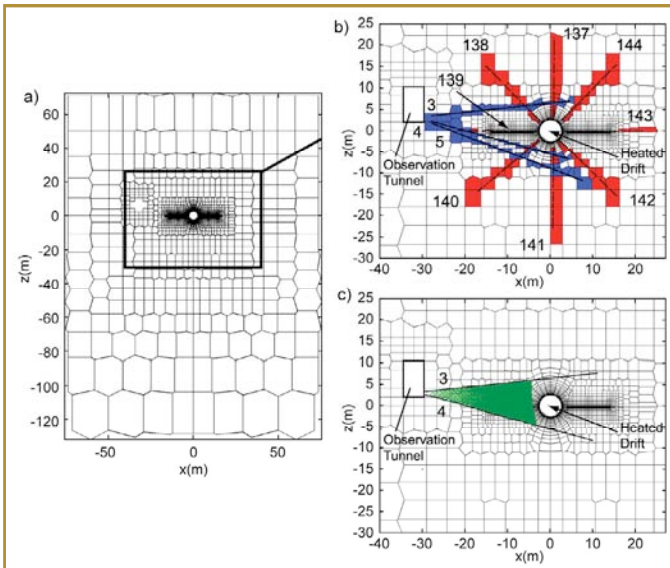

Figure 1. Thermal-hydrological model and measurement locations: (a) model grid; (b) locations of water content (measured by neutron probes) and temperature measurements (indicated by blue- and red-shaded gridblocks, respectively); and (c) locations for ground-penetrating radar data used for inversion (green lines connect transmitting and receiving antennas).

APPROACH

The approach integrates the coupled simulation of thermal-hydrological and geophysical data—ground-penetrating radar (GPR) data—within the iTOUGH2 optimization framework to estimate (1) thermal-hydrological parameters (such as permeability, porosity, thermal conductivity, and parameters of the capillary pressure and relative permeability functions) that are needed for predicting the flow of fluids and heat in fractured porous media; and (2) parameters of the petrophysical function that relates water saturation, porosity, and temperature to the dielectric constant.

ACCOMPLISHMENTS

We applied the approach to a large-scale *in situ* heater test that was conducted at Yucca Mountain, Nevada, to better understand the coupled thermal, hydrological, mechanical, and chemical processes that occur in the fractured rock mass around a geologic repository for high-level radioactive waste. We examined the sensitivity of the most relevant thermal-hydrological and petrophysical parameters to the time-lapse GPR data and thermal-hydrological data (temperature and water content) collected before and during the four-year heating phase of the test. To demonstrate the feasibility of the approach, and as a first step toward comprehensive inversion, we applied the approach to estimate the permeability of the rock matrix.

SIGNIFICANCE OF FINDINGS

Preliminary results indicate that estimation of thermal-hydrological and petrophysical parameters is possible through the combination of geophysical, hydrological, and thermal measurements. The large-scale heater test provides a unique data set to which our approach can be further applied and tested.

RELATED PUBLICATIONS

Kowalsky, M.B., J. Birkholzer, J. Peterson, S. Finsterle, S. Mukhopadhyay, and Y. Tsang, Sensitivity analysis for joint inversion of GPR and thermal-hydrological data from a large-scale underground heater test. Nuclear Technology (submitted), 2007.

Kowalsky, M., S. Finsterle, J. Peterson, S. Hubbard, Y. Rubin, E. Majer, A. Ward, and G. Gee, Estimation of field-scale soil hydraulic parameters and dielectric parameters through joint inversion of GPR and hydrological data. Water Resour. Res. 41, W11425, doi:10.1029/2005WR004237, 2005.

ACKNOWLEDGMENTS

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